Expanded Site Screening
North East Church Rock – Quivira Mines
Navajo Nation, New Mexico

EPA Contract No.: 91238-06-F-0083

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Prepared for:

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Region 9

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1.0 INTRODUCTION

This Expanded Screening Report is for use at the site of abandoned uranium mines (AUM) located on Navajo Nation lands. The purpose of the report is to ascertain the status and location of the identified AUM site area, to record all immediate site information associated with the mine site and to document the recommendation and/or decision on what additional steps, if any, are needed at the site.

The Northeast Church Rock – Quivira area was defined by the United States Environmental Protection Agency (EPA) to be within the general vicinity of two AUMs, Northeast Church No. 1 and Northeast Church Rock No. 1-East. The site area included the mine sites, the arroyos, drainages, roads, and surrounding features.

Weston Solutions, Inc. (Weston) screened the site area, and collected gamma radiation measurement through the vicinity of the site. The two individual AUMs were screened in October, 2008, and the surrounding areas were screened in October, 2009.

More information about the Superfund program is available on the EPA web site at http://www.epa.gov/superfund.

1.1 Navajo AUM Background Information

The lands of the Navajo Nation include 27,000 square miles spread over three states in the Four Corners area. The unique geology of these lands makes them rich in uranium, a radioactive ore in high demand after the development of atomic power and weapons at the close of World War II in the 1940s.From 1944 to 1986, nearly four million tons of uranium ore were extracted from Navajo lands under leases with the Navajo Nation. Many Navajo people worked the mines, often living and raising families in close proximity to the mines and mills.

Today the mines are closed, but a legacy of uranium contamination remains, including over 500 abandoned uranium mines as well as homes and drinking water sources with elevated levels of radiation. Potential health effects include lung cancer from inhalation of radioactive particles, as well as bone cancer and impaired kidney function from exposure to radionuclides in drinking water.

EPA maintains a strong partnership with the Navajo Nation and, since 1994, the Superfund Program has provided technical assistance and funding of over $13 million to assess potentially contaminated sites and develop a response. In August 2007, the Superfund Program compiled a Comprehensive Database and Atlas with the most complete assessment to date of all known uranium mines on the Navajo Nation. Working with the Navajo Nation, EPA also used its Superfund authority to clean up four residential yards and one home next to the highest priority abandoned uranium mine, Northeast Church Rock Mine, at a cost of more than $2 million.
At the request of the U.S. House Committee on Oversight and Government Reform in October 2007, EPA, along with the Bureau of Indian Affairs (BIA), the Nuclear Regulatory Commission

(NRC), the Department of Energy (DOE), and the Indian Health Service (IHS) developed a coordinated Five-Year Plan to address uranium contamination in consultation with Navajo Nation EPA. In May 2008 and September, EPA reported back to the Committee and to the Navajo Nation on its progress in implementing the Five-Year Plan.
The Five-Year Plan is the first coordinated approach created by the five federal agencies. This landmark plan outlines a strategy for cleanup and details the cleanup process for the Navajo Nation over the next five years.

EPA is addressing the most urgent risks on the reservation — uranium contaminated water sources and structures. Approximately 30 percent of the Navajo population does not have access to a public drinking water system and may be using unregulated water sources with uranium contamination. EPA and the Navajo Nation EPA have launched an aggressive outreach campaign to inform residents of the dangers of consuming contaminated water.
EPA will also continue to use its Superfund authority to address contaminated structures. EPA has already assessed more than 113 structures and yards and targeted at least 27 structures and 11 yards for remediation as a precaution.

Over the course of the Five-year Plan, EPA will focus on the problems posed by abandoned uranium mines, completing a tiered assessment of over 500 mines and taking actions to address the highest priority mines. As mines that pose risks are discovered, EPA may use Superfund authorities, including the National Priorities List, enforcement against responsible parties, or emergency response to require cleanup. In 2008 at the Northeast Church Rock Mine, the highest-risk mine on the Reservation, EPA is requiring the owner to conduct a cleanup that is protective of nearby residents. EPA's plan for addressing the remainder of contaminated soils at the site will be released for public comment in the summer of 2009.

Although the legacy of uranium mining is widespread and will take many years to address completely, the collaborative effort of EPA, other federal agencies and the Navajo Nation will bring an unprecedented level of support and protection for the people at risk from these sites. Much work remains to be done, and EPA is committed to working with the Navajo Nation to remove the most immediate contamination risks and to find permanent solutions to the remaining contamination on Navajo lands

2.0 BACKGROUND

2.1 Location

The Northeast Church Rock-Quivira site area is located approximately 16 miles northeast of the city of Gallup, New Mexico. The site area is immediately north of the intersection of Indian Route 566 and Red Water Pond Road. The Navajo Nation Chapters of Coyote Canyon, Nahodishgish, Pinedale, and Church Rock intersect near the site area. The site location is presented in Figure 1.

2.2 Site Description

The Northeast Church Rock – Quivira site area extent was determined by the EPA, in order to best characterize the radiological impact from uranium mining activities to the immediate surrounding areas. The sources investigated included Northeast Church Rock No. 1 mine, and the Northeast Church Rock No. 1-East mine. An additional source, the Northeast Church Rock mine, located directly south of the site area, was not investigated as part of the Northeast Church Rock-Quivira project. The Northeast Church Rock mine is currently being remediated, under the oversight of the EPA.

The Northeast Church Rock No. 1 mine site (Mine ID# 305, CERCLIS ID# NNSFN0905492), is located west of Indian Route 566, with geographic coordinates of 35.6654391042° N latitude, and -108.500960227° W longitude. The mine consists of an area of 169,958.9 square meters (m^2) with approximately 595,009 square meters of underground workings extending to the Northeast Church Rock No. 1-East mine. The site has been reclaimed, with no visible mine features observed at the mine site. The Northeast Church Rock No. 1 mine was screened by Weston in October 2008.

The Northeast Church Rock No. 1-East mine site (Mine ID# 303, CERCLIS ID# NNSFN0905492), is located along Indian Route 7049, approximately 0.5 miles east of the Northeast Church Rock No. 1 mine, with geographic coordinates of 35.6659628923° N latitude, and -108.489603164° W longitude. The mine consists of a surface area of 42,311.73 square meters with 389,847 square meters of underground workings extending to the Northeast Church Rock No. 1 mine. The site has been reclaimed, with no visible mine features observed at the mine site. The Northeast Church Rock No. 1-East mine was screened by Weston in October 2008.

Several areas of concern were identified by the EPA prior to the 2009 screening activities. These areas were chosen best characterize the impact of the mining operations on the surrounding area. The areas of concern included the arroyo/drainage area, the road and bridge area, the pond west of the Benally residence, and cornfield east of the Benally residence.

A series of arroyos (drainage washes) exist throughout the vicinity of the site area. An arroyo runs southwest, immediately east of Northeast Church Rock No. 1-East, and connects with an arroyo running southeast, south of Northeast Church Rock No. 1. During the gamma radiation screening, the arroyos were following upgradient and downgradient (including any encountered tributaries) in order to determine if any mining activities impacted the surrounding areas offsite. In all, approximately 4 miles of arroyo were screened.

The road and bridge area, located near the southwest corner of Northeast Church Rock No. 1 mine was determined to have elevated levels of gamma radiation, so a more in-depth screening process took place at the location. The bridge is located at the geographic coordinates of 35.6639475684° N latitude, and -108.503633242° W longitude.

A former pond and former cornfield, in the vicinity of the Benally residence were also determined to be a possible area of concern. The Benally residence is located approximately 0.8 miles west of the Northeast Church Rock No. 1 mine, with geographic coordinates of

35.66336565649° N latitude, and -108.518573265° W longitude. The former pond, with an approximate diameter of 500 feet, is located approximately 0.15 miles west of the residence. The cornfield, which is approximately 3.4 acres in size, is located approximately 0.2 miles east of the residence.

The screening procedures and findings are presented in Section 3.

2.3 Operational History

Little information was available detailing the historical operations at either of the Northeast Church Rock 1 or Northeast Church Rock 1-East mines. The Northeast Church Rock No. 1 mine was found to be operated by Kerr McGee from 1976 to 1985, primarily under the name of Kerr McGee Section 35. It was estimated that 3,139,784 pounds (lbs) of U_3O_8 was produced at the Northeast Church Rock No. 1 mine during operation.

The Northeast Church Rock No. 1-East mine was found to be operated by Kerr McGee from 1978 to 1983, primarily under the name of Kerr McGee Section 36. It was estimated that 1,447,463 lbs of U_3O_8 was produced at the Northeast Church Rock No. 1-East mine during operation.

The Northeast Church Rock mine, which is found south of the bridge, but is not part of the Northeast Church Rock-Quivira site area, was operational from 1968 to 1982. The shaft was developed in 1968 and 1969, and the mine was operated by the United Nuclear Corporation from 1972 to 1982. It was estimated that 10,000,000 lbs of U_3O_8 was produced at the mine during operation. The mine was closed in 1983, and dewatering took place. Between 1986 and 1994 the shaft was backfilled and capped, and the buildings were removed. Starting in 2007, air monitoring and soil sampling took place at and around the homes near the Northeast Church Rock mine. Since that time, several homes have been removed as a clean-up action led by the EPA has been underway, in order to remediate the vicinity of the mine site.

2.4 Regulatory Involvement

2.4.1 United States Environmental Protection Agency

From 1994 to 2007 EPA used its Superfund authority to conduct a thorough screening-level investigation, identifying approximately 1,100 mine features (portals, prospects, rim strips, pits, vertical shafts or waste piles) at 520 discrete abandoned mines throughout the Navajo Nation. EPA developed a Comprehensive Database and Atlas and a desktop risk ranking for all 520 mines. Using this information, EPA targeted 250 high-risk sites for further evaluation.

EPA also removed contaminated materials at several high-priority sites, and has expended over $13 million on the investigation and removals combined. EPA has consulted with Navajo Nation EPA and relied on its local knowledge at all phases of the investigation and removal actions.

Over the next five years, EPA will work with Navajo Nation EPA to conduct a tiered assessment of abandoned mines and to identify mines for further evaluation. On-site screening evaluations will be conducted for 200 to 250 mines and more detailed assessments will be completed at up to

35 mines. EPA will then work with Navajo Nation EPA to determine appropriate courses of action for the highest priority mines.

EPA will also to continue to pursue enforcement under Superfund, focusing on owners or operators of multiple mines. In April 2008, EPA sent information request letters to viable companies who owned or operated multiple mines

3.0 SITE SCREENING ASSESSMENT

3.1 Screening Procedures

The Northeast Church Rock – Quivira area was screened for gamma radiation by Weston during two separate events. In October 2008, Weston screened the Northeast Church Rock No. 1 and Northeast Church Rock No. 1-East mine sites. In October 2009, Weston screened the arroyos, the road and bridge area, and the Benally residence pond and cornfield.

In order to collect accurate gamma radiation measurements with corresponding locations, a Ludlum model 2221 ratemeter/scaler and model 44-10 gamma scintillation detector was synced with a Trimble GeoXT or ProXRT Global Positioning System (GPS) unit. The areas of concern were systematically scanned, and one reading per second was collected.

At the Northeast Church Rock No. 1 and Northeast Church Rock No. 1-East mine sites, the perimeters were scanned, followed by transects throughout the sites. In the arroyos, Weston scanned the base of the drainages, and followed any tributaries encountered along the path. The Benally pond and cornfield perimeters were scanned, followed by transects within the perimeter.

Subsurface screening was also conducted at selected locations throughout the site area, in order to determine if any elevated readings of gamma radiation exists below the surface level of the soil. The majority of the subsurface samples were collected within the arroyos, in order to determine if any contamination and been washed downgradient from the mining activities. A series of 3-inch diameter holes at various depths were dug using a hand auger, and gamma radiation readings, in counts per minute (cpm), were recorded as each depth was reached. Readings were generally collected at depths of 3-inches below ground surface (bgs), 1-foot bgs, 2-feet bgs, and 3-feet bgs.

In order to best represent the findings in the attached figures, Weston selected a univariate classification scheme based on a modified version of the Jenks Natural Breaks algorithm. The Jenks system is widely used in Geographic Information Systems (GIS) packages, including ESRI ArcGIS, used by Weston on the Northeast Church Rock – Quivira Mines project. Weston used this model as a basis to select the breaks used in the classification scheme. The actual breaks selected by Weston were determined based on additional factors, such as background gamma radiation measurements (13,615 cpm), Navajo Abandoned Mine Lands Reclamation Program action levels (50,000 cpm), and rounded break numbers, influenced by the Jenks model. An example of the classification scheme is shown in Figure 3, and can be compared to the scheme that has been used for the Navajo AUM site screenings in 2008 and 2009, as shown in Figure 10. A detailed description of the classification scheme is presented in Appendix A.

3.2 Screening Findings

Gamma radiation measurements collected by Weston were recorded in cpm, background gamma radiation measurements first had to be established in order to determine a basis for comparison. Background levels were collected from 9 separate locations, and composited background level of 13,615 was established. A list of background locations and levels is presented in Table 1.

A total for 24,012 gamma radiation measurements were collected by Weston at the Northeast Church Rock – Quivira site area. Measurements ranged from 8,587 cpm to 115,129 cpm. A list of measurement levels and locations is presented in Table 2. A map showing all the surface measurements as compared to background levels is presented in Figure 2. A map showing all the surface measurements in cpm is presented in Figure 3.

In October of 2008, surface gamma radiation levels were collected by Weston and the two mine sites, Northeast Church Rock No. 1 and Northeast Church Rock No. 1-East. Weston also collected some additional readings from the portion of Northeast Church Rock No.1 mine near the road and bridge area in October of 2009. In October of 2009, surface and subsurface measurements were collected from the arroyos, the road and bridge area, and the Benally pond and cornfield.

A total of 5,282 surface measurements were collected at the Northeast Church Rock No.1 mine, with levels ranging from 10,249 cpm to 115,129 cpm. The highest levels at the site were encountered in the southwestern and south-central areas of the site. A large graded reclaimed area is located at the southwest corner of the site, directly adjacent to the road and bridge area. A map showing the surface measurements at Northeast Church Rock No.1 mine are presented in Figure 4.

A total of 3,243 surface measurements were collected at the Northeast Church Rock No.1-East mine, with levels ranging from 10,001 cpm to 101,193 cpm. The highest levels at the site were encountered in the central areas of the site. A map showing the surface measurements at Northeast Church Rock No.1 mine are presented in Figure 5.

A total of 8,626 surface measurements were collected from the approximately 4-miles of arroyos throughout the site area. Measurements ranged from 8,587 cpm to 36,333 cpm. The entire arroyo system, with the exception of one spot immediately east of the Northeast Church Rock No. 1-East outfall, was found to be at or near background levels. A map showing the surface measurements of the entire arroyo system is presented in Figure 3.

A total of 4,357 surface measurements were collected from the road and bridge area, which crosses the arroyo south of Northeast Church Rock No.1, and turns adjacent to the southwest corner of the mine. Measurements ranged from 13,535 cpm to 95,365 cpm. The highest measurements were encountered along the side of the road, on both the northern and southern sides of the bridge. The measurements were significantly lower after the road turns to the west, north of the bridge. Measurements collected in the arroyo directly below the bridge were found to be at or near background levels, so it did not appear that the contamination was migrating significantly into the arroyo. The bridge itself was also found to have elevated levels, approaching 75,000 cpm. A map showing the surface measurements of the road and bridge area are presented in Figure 6.

A total of 1,349 surface measurements were collected from the Benally cornfield. Measurements ranged from 10,024 cpm to 18,136 cpm. The entire former cornfield area was found to be at or near background levels. A map showing the surface measurements of the cornfield is presented in Figure 7.

A total of 1,155 surface measurements were collected from the Benally pond. Measurements ranged from 10,206 cpm to 18,333 cpm. The entire former pond area was found to be at or near background levels. A map showing the surface measurements of the pond is presented in Figure 7.

Subsurface gamma radiation measurements were collected from selected locations at varying depths throughout the site area. A total 80 measurements were collected from 21 discrete locations, and depth ranging from 3-inches bgs to 3-feet bgs. A summary of the subsurface measurements and locations are presented in Table 3, and Figures 8 and 9.

A total of 14 subsurface collection locations were situated in the arroyo system. All of the measurements collected in the arroyos were found to be less than two times the background level, and ranged from 10,097 cpm to 26,223 cpm. The readings were generally consistent, where the measurements tended to be slightly lower at the top (3-inches bgs) and then moderately higher with depth. The Ludlum 2221 used during the screening collects readings from 360°, so it possible that the lowest reading consistently was found at the shallowest depth due the surface/air exposure at the top.

A total of 2 subsurface collection locations were situated at the Benally pond, one collected at the center of the former pond, and one in the pond drainage channel. All of the measurements collected at the pond were found to be less than two times the background level, and ranged from 15,316 cpm to 23,408 cpm. As with the arroyo subsurface measurement, the pond measurement were found to be slightly lower at the shallower depths.

A total of 5 subsurface collection locations were situated on the north side of the bridge. Significant elevated measurements were recorded in all 5 subsurface location, and at all depths. The measurements ranged from 21,809 cpm to 176,871. Unlike the arroyo and pond subsurface samples, the highest readings were generally found at the 1-foot and 2-feet bgs intervals, while the lower readings were found at the 3-inch and 3-feet intervals. This pattern may indicate the at the surface contamination may have been removed, covered, or eroded over the passage of time, and with the levels decreasing beyond 2-feet bgs it may indicate that the contamination has not migrated deeper into the soil.

A summary of the subsurface measurements and locations are presented in Table 3, and Figures 8 and 9.

4.0 SUMMARY

The Northeast Church Rock – Quivira area was defined by the EPA to be within the general vicinity of two AUMs, Northeast Church No. 1 and Northeast Church Rock No. 1-East. The site area included the mine sites, arroyos, drainages, roads, and surrounding features. The site area is located approximately 16 miles northeast of the city of Gallup, New Mexico. The site area is immediately north of the intersection of Indian Route 566 and Red Water Pond Road. The Navajo Nation Chapters of Coyote Canyon, Nahodishgish, Pinedale, and Church Rock intersect near the site area.

The Northeast Church Rock – Quivira site area extent was determined by the EPA, in order to best characterize the radiological impact from uranium mining activities to the immediate surrounding areas. The sources investigated included Northeast Church Rock No. 1 mine, and the Northeast Church Rock No. 1-East mine. An additional source, the Northeast Church Rock mine, located directly south of the site area, was not investigated as part of the Northeast Church Rock-Quivira project. The Northeast Church Rock mine is currently being remediated, under the oversight of the EPA.

Both Northeast Church Rock No. 1 and Northeast Church Rock No. 1-East appear to have been reclaimed with no visible mine features observed at either mine site. Both mines were screened by Weston in October 2008. Little historical information was available for either of the mines, although they were shown to be operated by Kerr McGee from the mid-1970s to the early 1980s, under the names Kerr McGee Section 35 and Kerr McGee Section 36.

Several areas of concern were identified by the EPA prior to the 2009 screening activities. These areas were chosen best characterize the impact of the mining operations on the surrounding area. The areas of concern included the arroyo/drainage area, the road and bridge area, the pond west of the Benally residence, and cornfield east of the Benally residence.

A series of arroyos exist throughout the vicinity of the site area. In all, approximately 4 miles of arroyo were screened. The road and bridge area, located near the southwest corner of Northeast Church Rock No. 1 mine was determined to have elevated levels of gamma radiation, so a more in-depth screening process took place at the location. A former pond and former cornfield, in the vicinity of the Benally residence were also determined to be a possible area of concern. .

In order to collect accurate gamma radiation measurements with corresponding locations, a Ludlum model 2221 ratemeter/scaler and model 44-10 gamma scintillation detector was synced with a Trimble GeoXT or ProXRT GPS unit. The areas of concern were systematically scanned, and one reading per second was collected.

At the Northeast Church Rock No. 1 and Northeast Church Rock No. 1-East mine sites, the perimeters were scanned, followed by transects throughout the sites. In the arroyos, Weston scanned the base of the drainages, and followed any tributaries encountered along the path. The Benally pond and cornfield perimeters were scanned, followed by transects within the perimeter.

Gamma radiation measurements collected by Weston were recorded in cpm, background gamma radiation measurements first had to be established in order to determine a basis for comparison.

Background levels were collected from 9 separate locations, and composited background level of 13,615 was established.

A total of 24,012 gamma radiation measurements were collected by Weston at the Northeast Church Rock – Quivira site area. Measurements ranged from 8,587 cpm to 115,129 cpm. Surface measurements were collected at the Northeast Church Rock No.1 mine, with levels ranging from 10,249 cpm to 115,129 cpm. Surface measurements were collected at the Northeast Church Rock No.1-East mine, with levels ranging from 10,001 cpm to 101,193 cpm. Surface measurements were collected from the approximately arroyos throughout the site area, with levels ranging from 8,587 cpm to 36,333 cpm. Surface measurements were collected from the road and bridge area, with levels ranging from 13,535 cpm to 95,365 cpm. Surface measurements were collected from Benally cornfield, with levels ranging from 10,024 cpm to 18,136 cpm. Surface measurements were collected from the Benally pond, with levels ranging from 10,206 cpm to 18,333 cpm.

Subsurface screening was also conducted at selected locations throughout the site area, in order to determine if any elevated readings of gamma radiation exists below the surface level of the soil. Subsurface gamma radiation measurements were collected from selected locations at varying depths throughout the site area. A total 80 measurements were collected from 21 discrete locations, and depth ranging from 3-inches bgs to 3-feet bgs.

A total of 14 subsurface collection locations were situated in the arroyo system, with levels ranging from 10,097 cpm to 26,223 cpm. A total of 2 subsurface collection locations were situated at the Benally pond, one collected at the center of the former pond, and one in the pond drainage channel, with levels ranging from 15,316 cpm to 23,408 cpm.

A total of 5 subsurface collection locations were situated on the north side of the bridge. Significant elevated measurements were recorded in all 5 subsurface locations, and at all depths. The measurements ranged from 21,809 cpm to 176,871. The highest readings were generally found at the 1-foot and 2-feet bgs intervals, while lower readings were found at the 3-inch and 3-feet intervals. This pattern may indicate the at the surface contamination may have been removed, covered, or eroded over the passage of time, and with the levels decreasing beyond 2-feet bgs it may indicate that the contamination has not migrated deeper into the soil.

FIGURES

Figure 1
Site Location
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

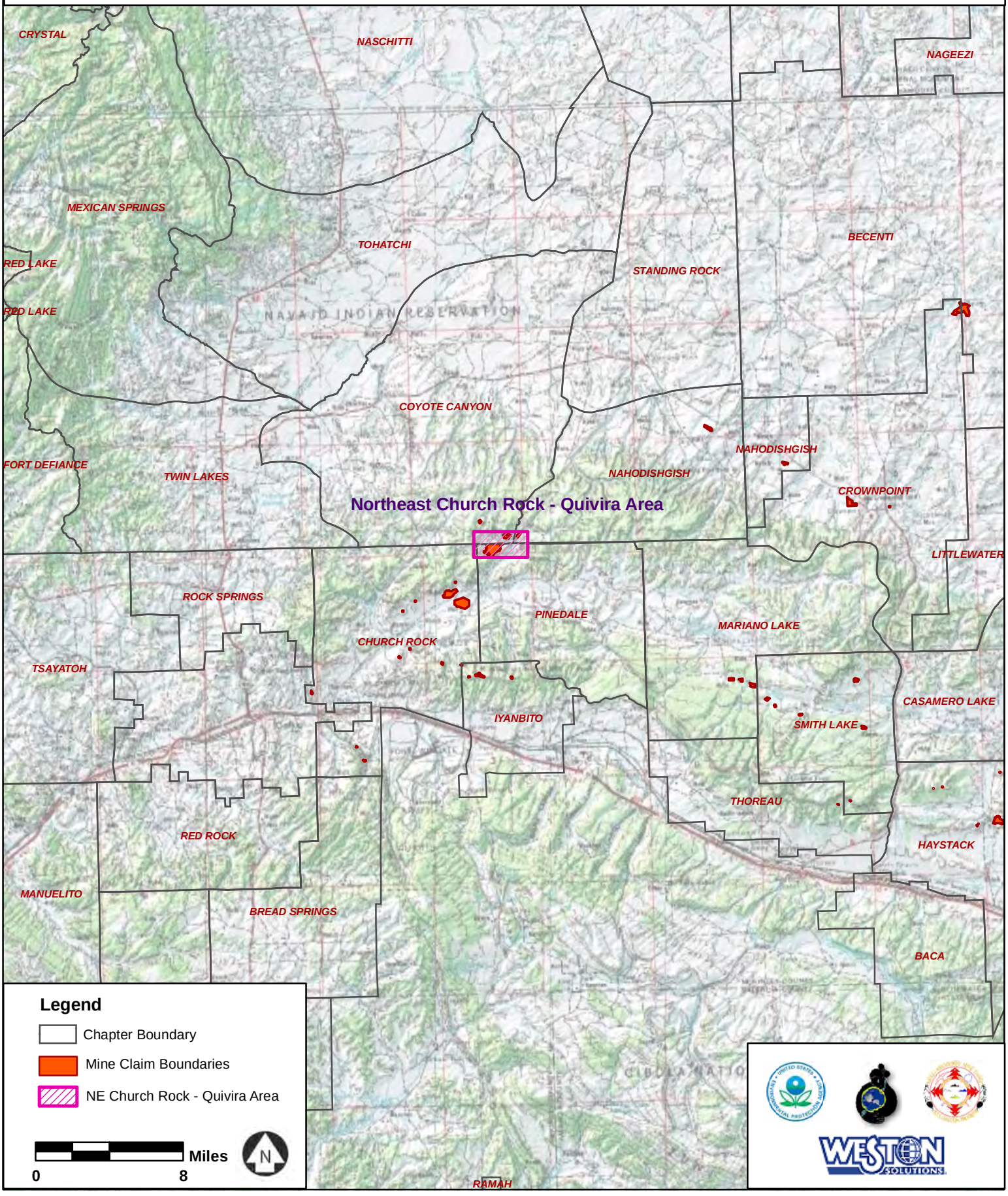


Figure 2
Surface Gamma Radiation Measurements Compared To Background
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

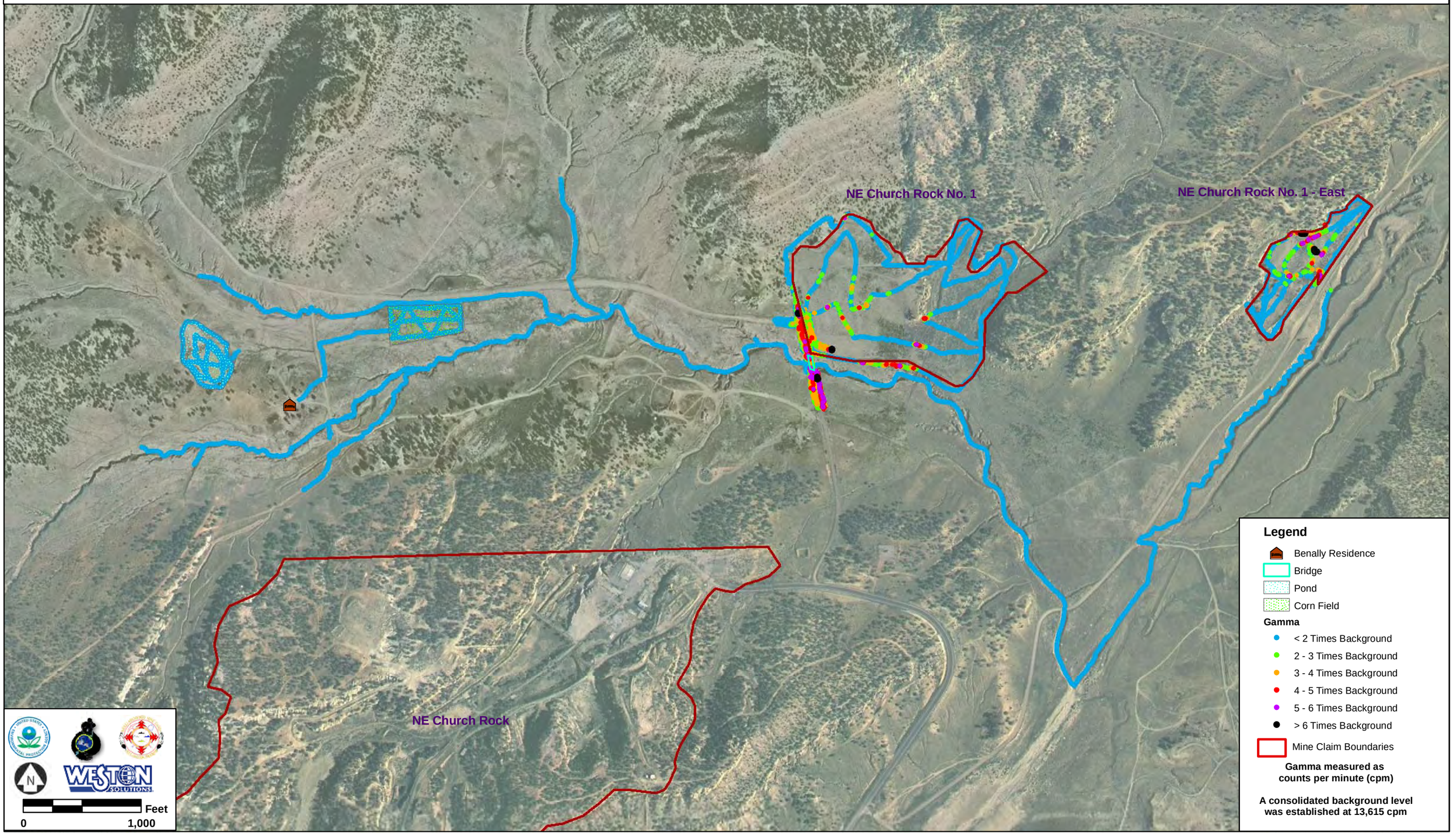


Figure 3
Surface Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

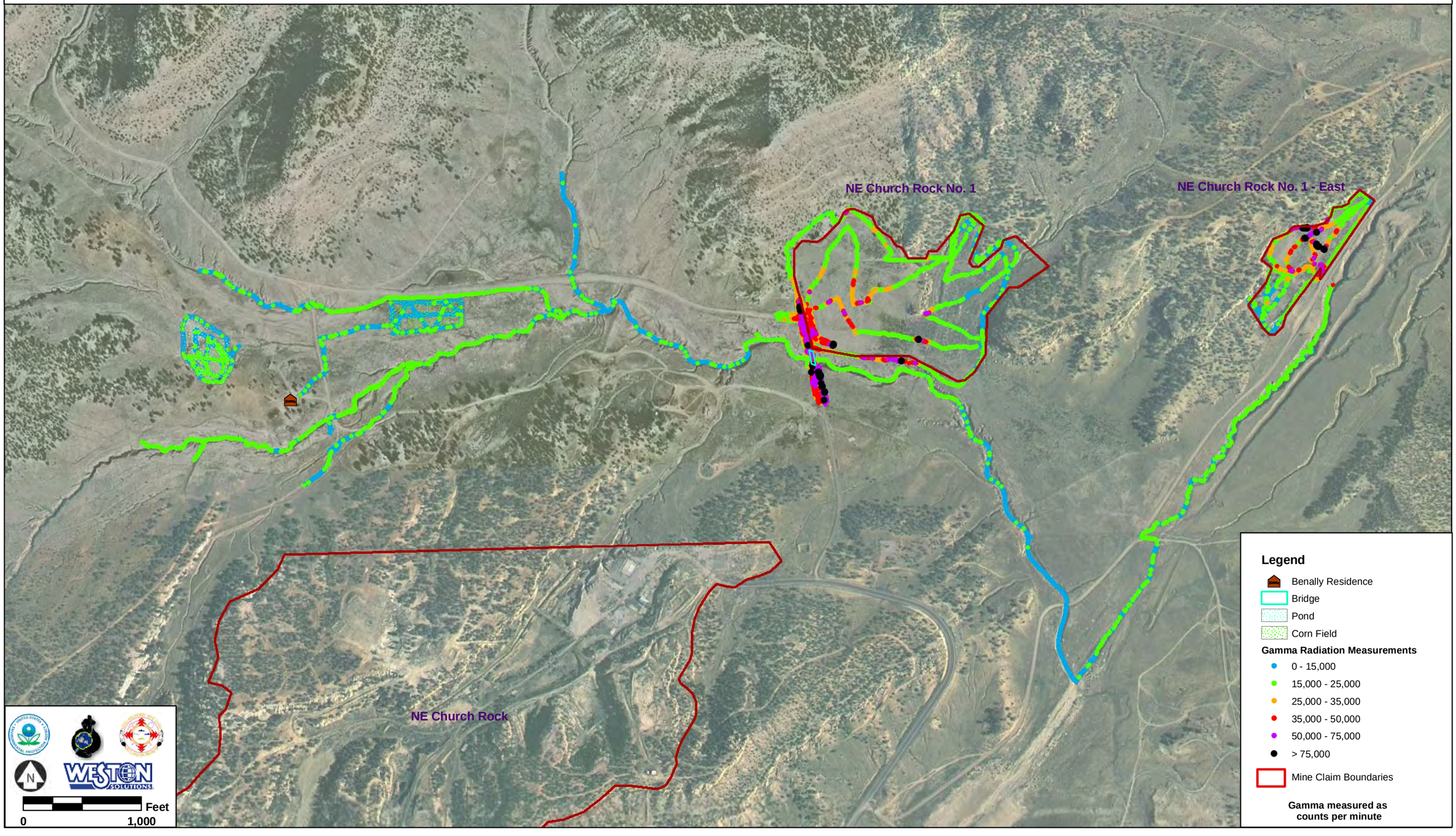


Figure 4
Northeast Church Rock No. 1-East Mine Site Area Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

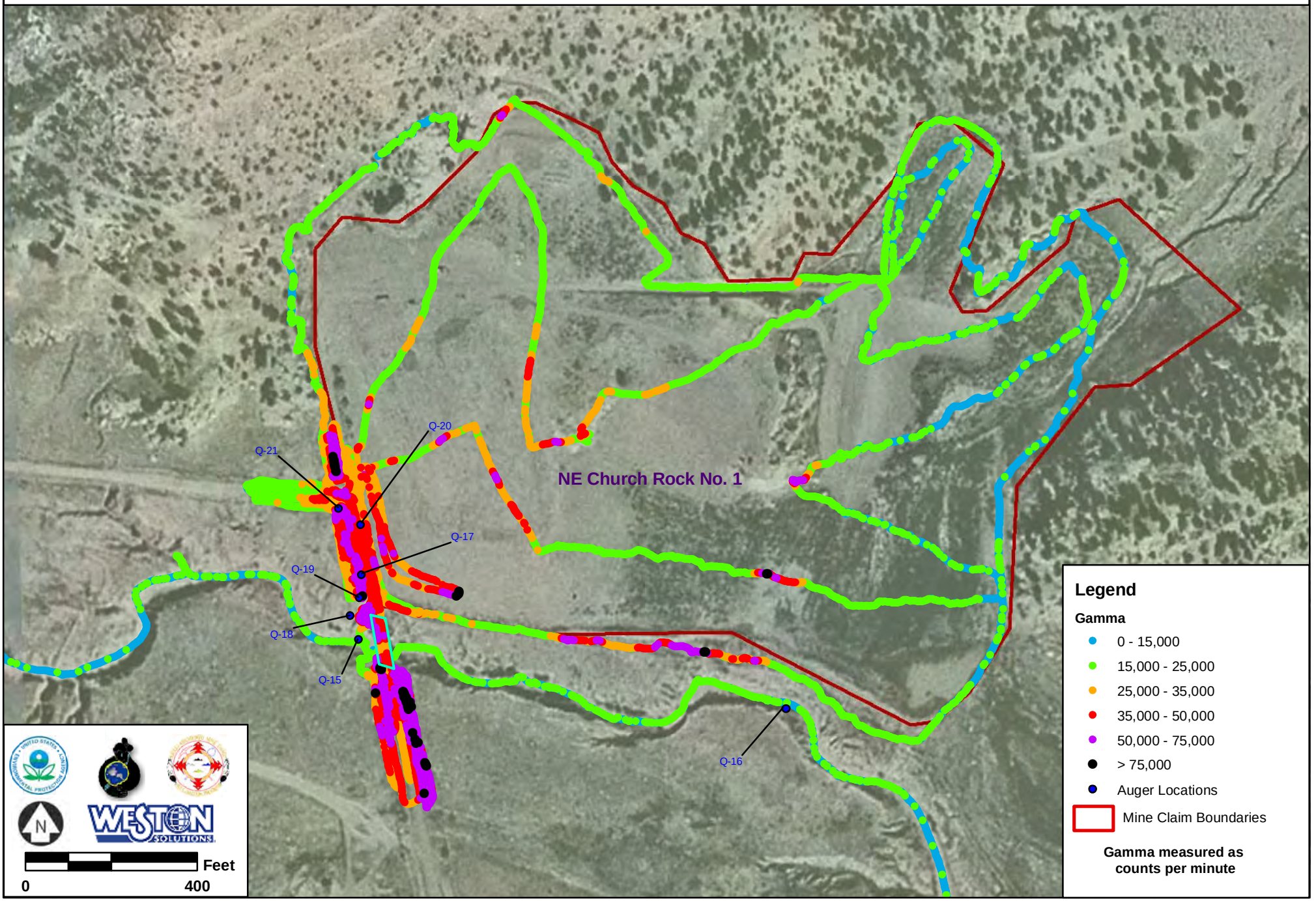


Figure 5
Northeast Church Rock No. 1-East Mine Site Area Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

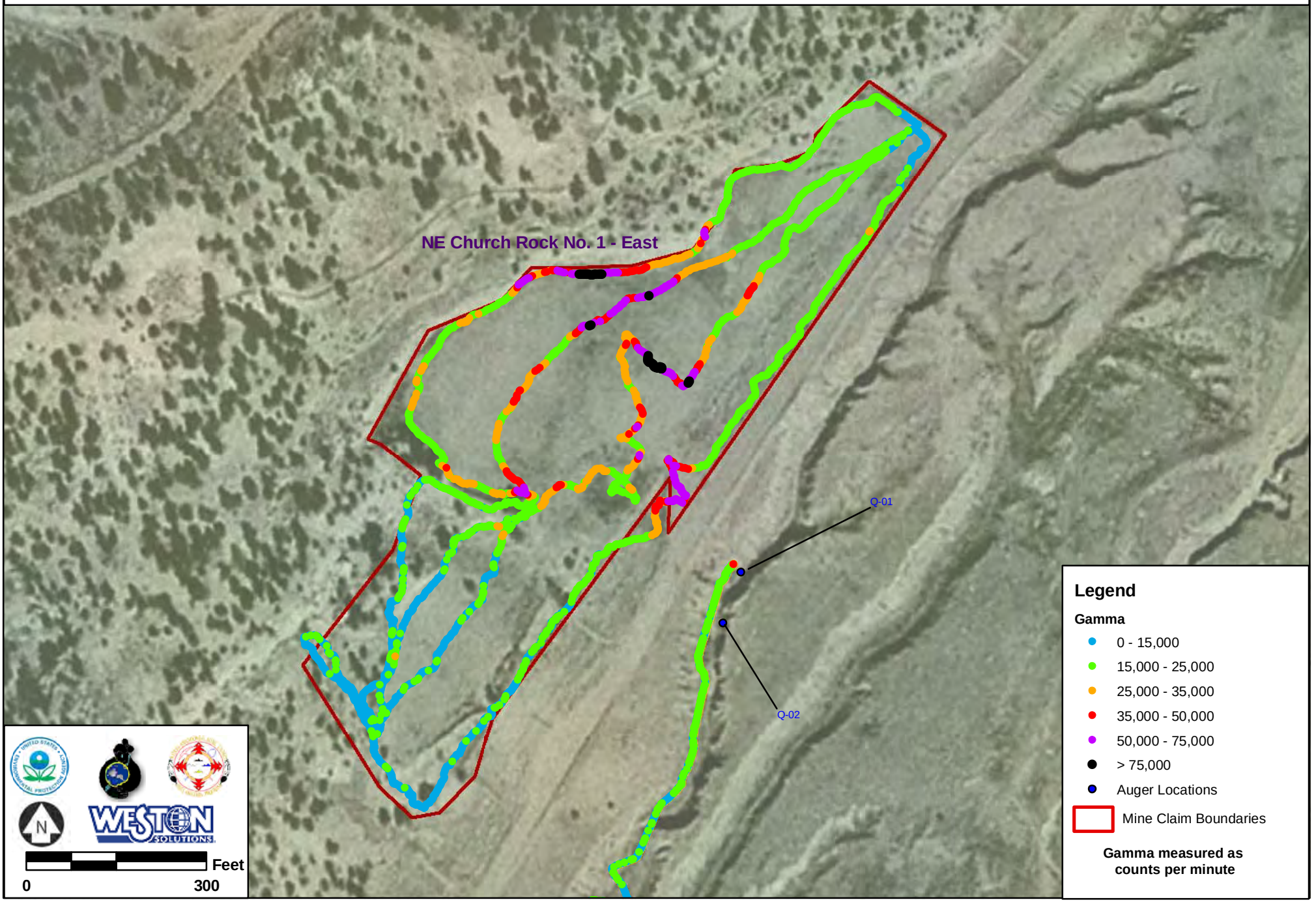


Figure 6
Road and Bridge Area Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

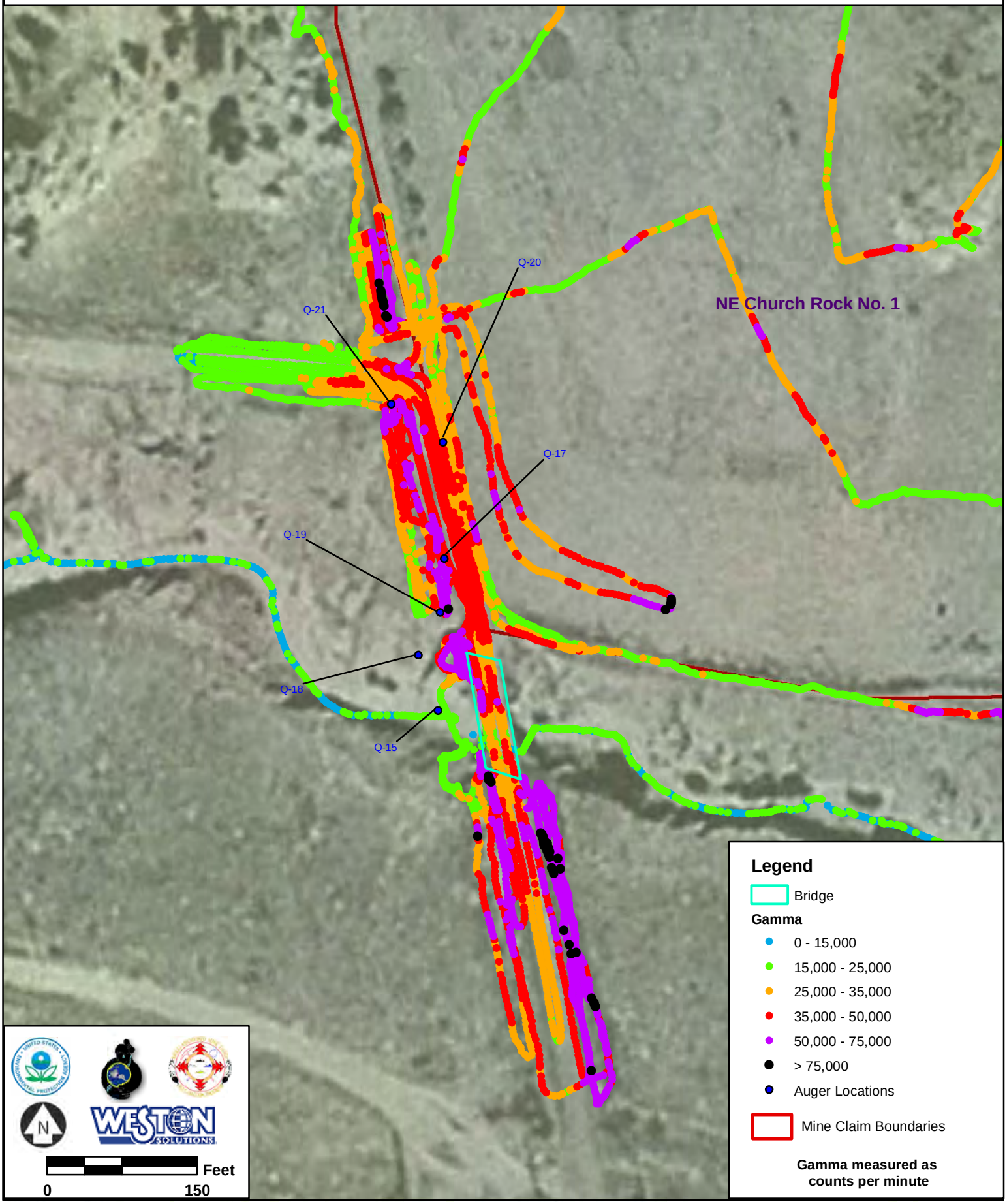


Figure 7
Western Area Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

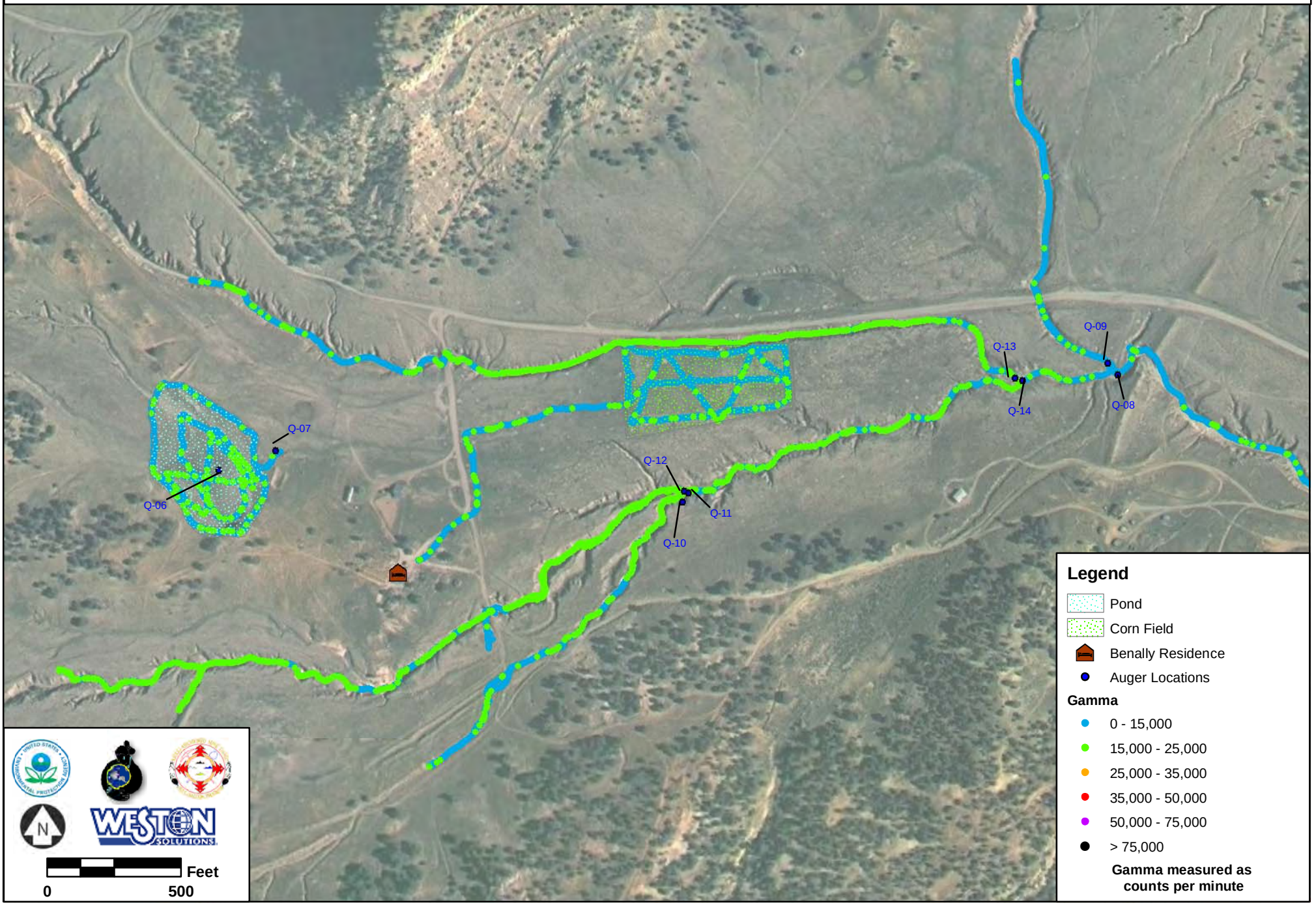


Figure 8
Surface and Subsurface Background Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

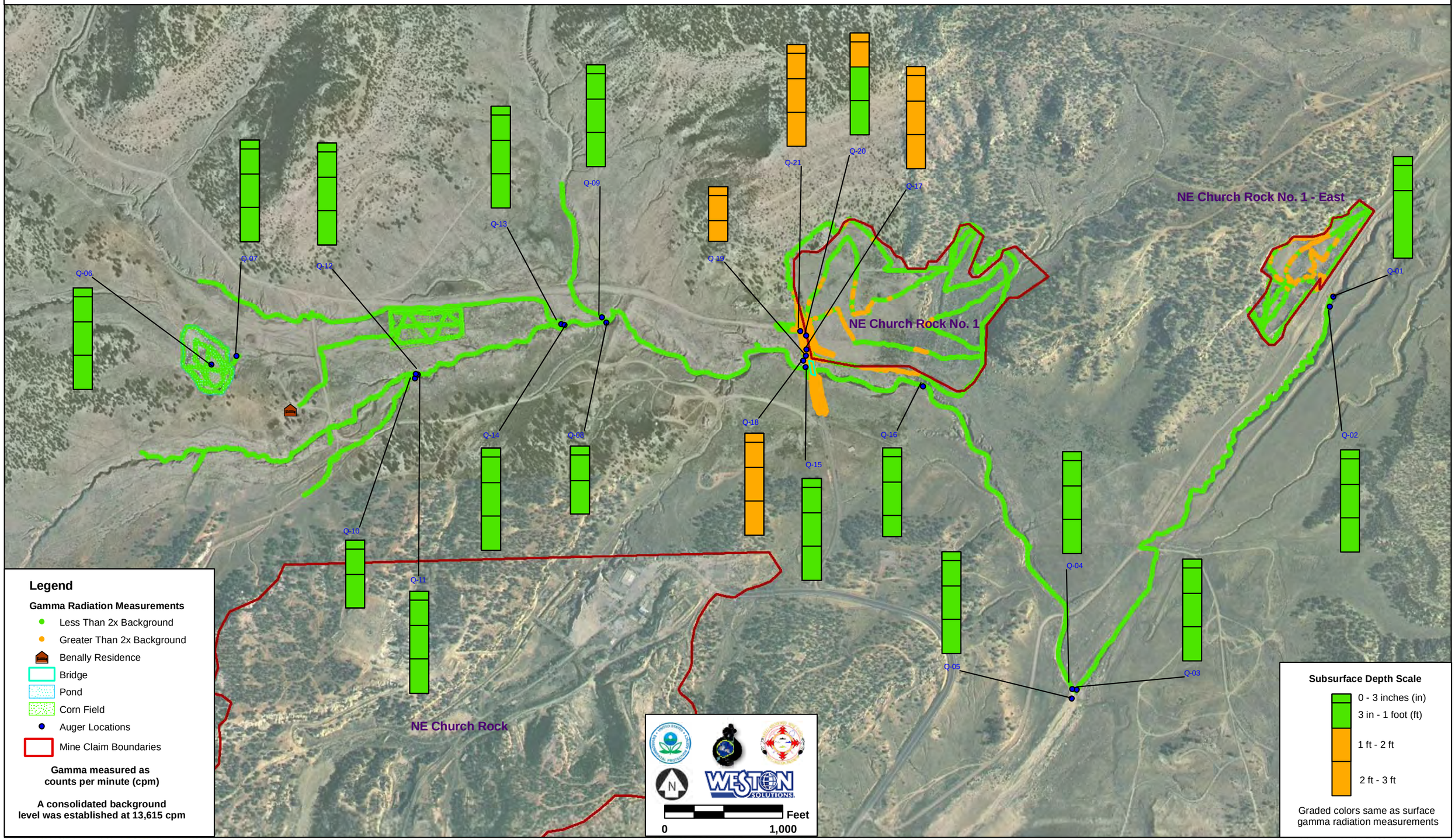


Figure 9
Surface and Expanded Subsurface Gamma Radiation Measurements
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico

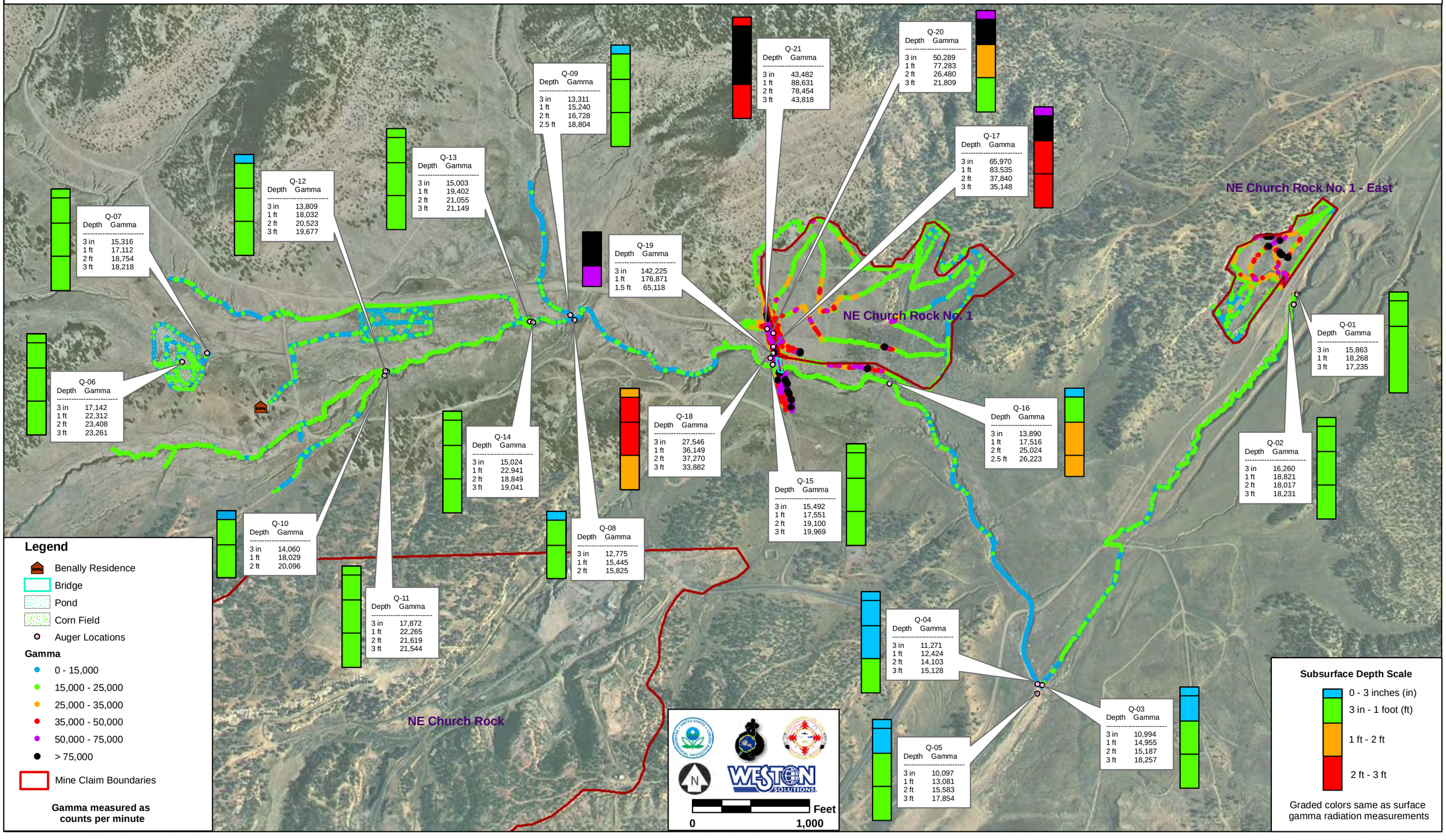
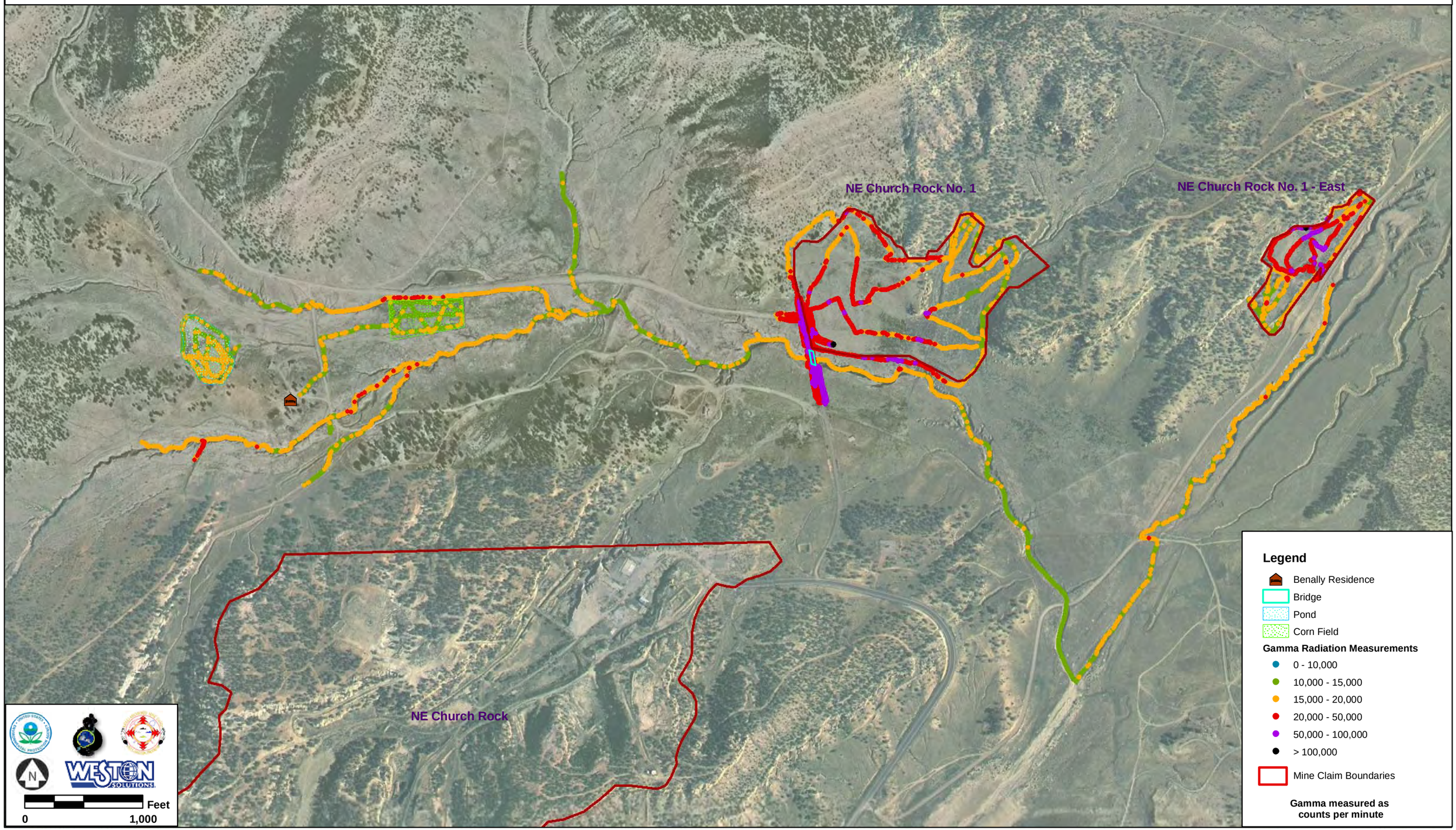


Figure 10
Surface Gamma Radiation Measurements with Navajo AUM Site Screening Color Classification Scheme
Northeast Church Rock - Quivira Mines
Navajo Nation, New Mexico



TABLES

Table 1
Northeast Church Rock - Quivira Mines
Background Gamma Radiation Measurements
Navajo Nation, New Mexico

Background Location	Gamma Measurement
Extent of Northern Wash	12,668
Extent of Northwest Wash	14,210
Extent of Southwest Wash	13,523
Extent of South Wash	12,984
Vicinity of NE Church Rock 1-East Mine (measured 10/2008)	12,802
Vicinity of NE Church Rock 1-East Mine (measured 10/2008)	13,017
Vicinity of NE Church Rock 1-East Mine (measured 10/2008)	13,365
Vicinity of NE Church Rock 1 Mine (measured 10/2008)	14,543
Vicinity of NE Church Rock 1 Mine(measured 10/2008)	15,421
Consolidated Average Background Level	13,615

Gamma measurements in counts per minute (cpm)

Table 2
Norteast Church Rock -Quivira Mines
Surface Gamma Radiation Measurements
Navajo Nation, New Mexico

Location	Gamma Minimum	Gamma Maximum	No. Gamma Readings
Quivira Bridge / Road	13,535	95,365	4,357
Quivira Wash - East of Bridge	8,587	36,333	4,270
Quivira Wash - West of Bridge	9,518	23,205	4,356
Benally Corn Field	10,024	18,333	1,349
Benally Pond	10,206	18,186	1,155
Northeast Church Rock 1	10,249	115,129	5,282
Northeast Church Rock 1 East	10,001	101,193	3,243

Gamma measurements in counts per minute (cpm)

Table 3
Northeast Church Rock -Quivira Mines
Subsurface Gamma Measurement Locations
Navajo Nation, New Mexico

Location ID	Loation Description	Depth	Gamma	Comments
Q01	North of NE Church Rock 1-East Culvert	3 in	15,863	
		1 ft	18,268	
		2 ft	-	No reading collected at 2 ft
		3 ft	17,235	
Q02	South of NE Church Rock 1-East Culvert	3 in	16,260	
		1 ft	18,821	
		2 ft	18,017	
		3 ft	18,231	
Q03	Downstream if NE Church Rock 1-East	3 in	10,994	
		1 ft	14,995	
		2 ft	15,187	
		3 ft	18,257	
Q04	Connection of Washes from NE Church Rock 1-East and NE Chruch Rock 1	3 in	11,271	
		1 ft	12,424	
		2 ft	14,103	
		3 ft	15,128	
Q05	Downstream of Connection of Washes from NE Church Rock 1-East and NE Chruch Rock 1	3 in	10,097	
		1 ft	13,081	
		2 ft	15,583	
		3 ft	17,854	
Q06	Pond Near Benally Residence	3 in	17,142	
		1 ft	22,312	
		2 ft	23,408	
		3 ft	23,261	
Q07	Pond Near Benally Residence Drainage	3 in	15,316	
		1 ft	17,112	
		2 ft	18,754	
		3 ft	18,218	
Q08	North Wash, Downstream	3 in	12,775	
		1 ft	15,445	
		2 ft	15,825	
		3 ft	-	Collapsing at 2 ft
Q09	North Wash, Upstream	3 in	13,311	
		1 ft	15,240	
		2 ft	16,728	
		2.5 ft	18,804	Wet at 2.5 ft
Q10	South Wash, Upstream	3 in	14,060	
		1 ft	18,029	
		2 ft	20,096	
		3 ft	-	Collapsing at 2 ft
Q11	South Wash and Southwest Wash, Downstream	3 in	17,872	
		1 ft	22,265	
		2 ft	21,619	
		3 ft	21,544	
Q12	Southwest Drainage, Upstream	3 in	13,809	
		1 ft	18,032	
		2 ft	20,523	
		3 ft	19,677	
Q13	Northwest Drainage, Upstream	3 in	15,003	
		1 ft	19,402	
		2 ft	21,055	
		3 ft	21,149	

Table 3
Northeast Church Rock -Quivira Mines
Subsurface Gamma Measurement Locations
Navajo Nation, New Mexico

Location ID	Loation Description	Depth	Gamma	Comments
Q14	Northwest Drainage, Downstream	3 in	15,024	
		1 ft	22,941	
		2 ft	18,849	
		3 ft	19,041	
Q15	Upstream of Northeast Church Rock 1	3 in	15,492	
		1 ft	17,551	
		2 ft	19,100	
		3 ft	19,969	
Q16	Downstream of Northeast Church Rock 1	3 in	13,890	
		1 ft	17,516	
		2 ft	25,024	
		2.5 ft	26,223	Refusal at 2.5 ft
Q17	West Side of Road, South of Culvert	3 in	65,970	
		1 ft	83,535	
		2 ft	37,840	
		3 ft	35,148	
Q18	Drainage to Wash, North of Bridge	3 in	27,546	
		1 ft	36,149	
		2 ft	37,270	
		3 ft	33,882	
Q19	Above Drainage, North of Bridge	3 in	142,225	
		1 ft	176,871	
		1.5 ft	65,118	Refusal at 1.5 ft
		3 ft	-	
Q20	East Side of Road, Along Fence for NE Church Rock 1	3 in	50,289	
		1 ft	77,283	
		2 ft	26,490	
		3 ft	21,809	
Q21	Directly South of Culvert, Near Road Corner	3 in	43,482	
		1 ft	88,631	
		2 ft	78,454	
		3 ft	43,818	

Gamma measurements in counts per minute (cpm)

APPENDIX A:

Univariate Classification Scheme & Break Selection Graphs

Selection of the Univariate Classification Scheme
Northeast Church Rock – Quivira Mines Area

Weston selected a univariate classification scheme based on a modified version of the Jenks Natural Breaks algorithm. The Jenks system is widely used in Geographic Information Systems (GIS) packages, including ESRI ArcGIS, used by Weston on the Northeast Church Rock – Quivira Mines project. The Jenks system can be defined in the following steps:

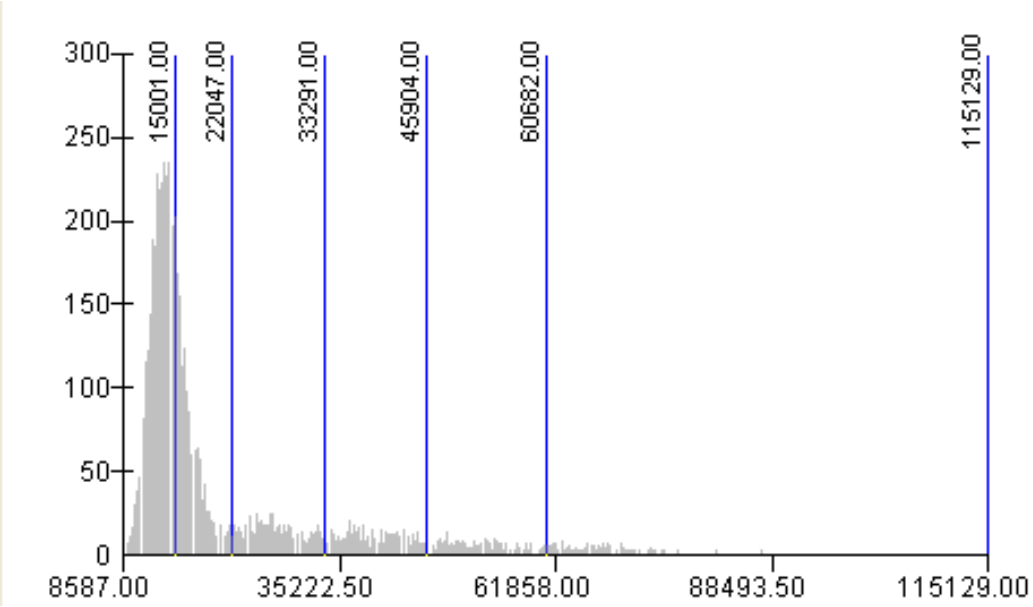
1: A user (*Weston*) selects and *x* attribute *(Gamma Radiations Measurements)*, to be classified and specifies the number of classes to be used, *k (6)*

2: *k*-1 uniform values are selected in the range (*Gamma Radiation minimum 8,587; and maximum 115,129, as measured in counts per minute (cpm)*), and are used as initial class boundaries.

3: The mean values for each initial class are calculated by the GIS system and the sum of squared deviations of class members from the mean values is calculated, and the total sum of squared deviations (TSSD) is recorded.

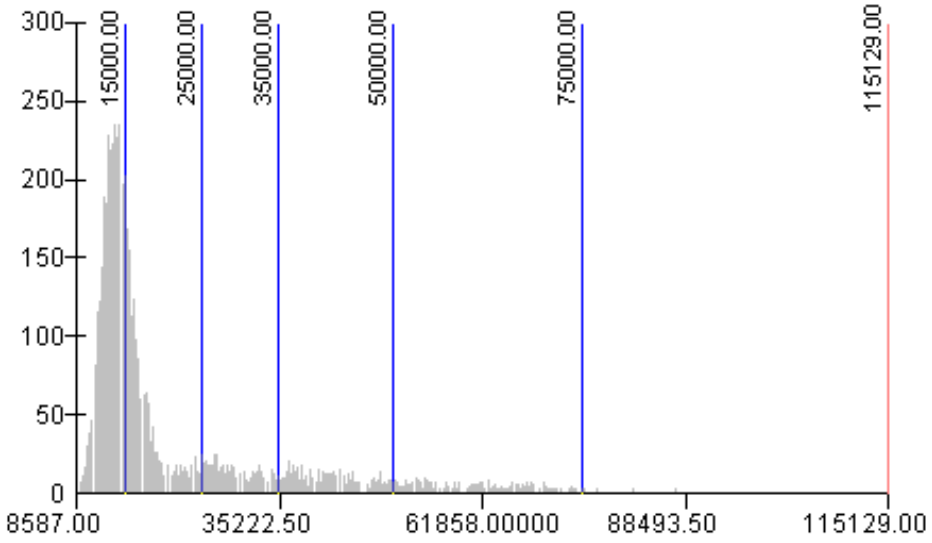
4: Individual values in each class are then systematically assigned to adjacent classes by adjusting the class boundaries to see if the TSSD can be reduced. This process ends when the variance within each class is as small as possible and variance between each class is as large as possible.

The following model was created by ESRI ArcGIS using the Jenks method:



Weston used this model as a basis to select the breaks used in the classification scheme. The actual breaks selected by Weston were determined based on additional factors, such as background gamma radiation measurements (13,615 cpm), Navajo Abandoned Mine Lands Reclamation Program action levels (50,000 cpm), and rounded break numbers, influenced by the Jenks model.

The following breaks were selected by Weston for the Northeast Church Rock – Quivira Mines project:



Natural breaks as determined by Jenks method	Breaks selected by Weston for project
8,587 – 15,001 cpm	8,587 – 15,000 cpm
15,001 – 22,047 cpm	15,000 – 25,000 cpm
22,047 – 33,291 cpm	25,000 – 35,000 cpm
33,291 – 45,904 cpm	35,000 – 50,000 cpm
45,904 – 60,682 cpm	50,000 – 75,000 cpm
60,682 – 115,129 cpm	75,000 – 115,129 cpm

APPENDIX B:

Interpretation of Gross Gamma Data Applied to the Northeast Church Rock – Quivira Site Area

Interpretation of Gross Gamma Data Applied to Navajo AUM Criteria

The Navajo use the following two criteria to evaluate residual radiological contamination at abandoned uranium mine (AUM) sites:

1. The site must have a residual gamma exposure rate of less than 50 microRoentgens per hour (uR/h) inclusive of the natural background exposure rate, and
2. The residual concentrations of Ra-226 must be less than 5 pCi/g in the top 6 inches of soil and less than 15 pCi/g at depths greater than 6 inches greater than the natural background concentration for Ra-226 in the area.

Weston Solutions, Inc. (WESTON) measured gross gamma count rates with 2X2 NaI detectors held approximately 18 inches above the ground surface at hundreds of AUM sites as an indicator of the current radiological conditions at each mine site. It is important to understand the value of those data, and the limitations of their uses when reviewing the results provided in the individual Site Screen Reports, as indicated herein.

1. The gamma measurements used for these site assessments are intended to establish the range of gamma radiation levels at each mine site for comparison to approximate background values and are not intended for comparison to the two criteria mentioned above. There are no de facto mathematical conversion factors that will convert the gamma readings in cpm to provide accurate and reliable determinations of exposure rates in μR/hr or Ra-226 concentrations in pCi/g.
2. Under certain conditions gamma scanning measurements such as those used for these site assessments are often used for site characterization and evaluation, neither of which is within the scope of these site assessments. When used for site characterization or evaluation, gamma readings are often converted to exposure rates or concentrations by empirical means. For conversion to exposure rates, numerous side-by-side readings are taken at a wide range of exposure levels under controlled conditions using the gamma detector and a pressurized ion chamber, which is barely a portable instrument and is not particularly rugged, so is not well suited to the conditions of these assessments. For conversion to soil concentrations, numerous gamma readings are taken and soil samples collected from the precise locations of the readings. For both conversions, the resulting data are graphed and linear regression analyses performed to establish a correlation line for the conversion equation.
3. Neither of the two processes describe in item 2 were within the scope of these site assessments, nor were they feasible under the conditions encountered. The range of geological conditions that existed from one mine location to another would have required that each mine site, or group of closely co-located mine sites, be considered as separate study areas, and the time to conduct such correlation studies would have been prohibitive.
4. Many such correlation studies have been conducted for uranium-contaminated sites, but the conditions for each study have been closely controlled, which is not possible for the hundreds of abandoned mine sites included in these assessments. Even with closely controlled site conditions the correlation studies are approximations at best. The soil concentration correlations are negatively impacted by buried contaminants and non-

homogeneous contaminant conditions, and the exposure rate correlations are negatively impacted by variations in the presence of higher energy gamma emitters.

5. In order to address the likely inclination of those who will read these Site Screen Reports to interpret the gross gamma results in terms of exposure rates or soil concentrations, the following text summarizes information about the uranium decay chain, its associated gamma rays, and how the gamma ray energies would impact exposure rates and correlate to soil concentrations. This information is notbased on site-specific measurements and cannot be strictly applied to these data, but may allow some approximate comparisons of the relative gamma levels to exposure rates and soil concentrations resulting in roughly estimated values for comparison to the two criteria used by the Navajo.

Converting Gross Gamma Count Rate Data to µR/h

Natural uranium undergoes radioactive decay to stable lead via a series of radioactive elements called progeny or daughter radionuclides. Uranium-238 (U-238) is the parent radionuclide for the decay series and it does not emit a gamma ray detectable by field instruments. However, several of the 13 primary daughter radionuclides emit multiple gamma rays which can be detected.

Material that contains only the parent U-238 isotope will accumulate increasing concentrations of the daughter radionuclides over time, eventually reaching a point at which all of the radionuclides are present in equal activity concentrations. This is termed secular isotopic equilibrium and is attained in uranium deposits after a few million years if mineralization behaves in a closed geochemical system so that none of the daughter radionuclides are removed from the material as they are produced. Secular equilibrium is the steady state condition where all progeny nuclides have the same activity as their parent.

Figure 1 depicts a typical gamma ray spectrum of U-238 ore with a few of the primary gamma peaks from progeny identified by their respective energies. This figure shows the relative abundance of the gamma ray energies from thorium-234 (Th-234), radium-226 (Ra-226), lead-214 (Pb-214), and bisthmuth-214 (Bi-214), all of which are U-238 progeny. The majority of the gamma rays associated with U-238 have energies less than the 609 keV of Bi-214, as shown in Figure 1 by the decline in the curve beyond the energy of Bi-214. The relative abundance of these gamma ray energies is important because the detectors used to measure gamma radiation levels in the field show a variable response based on the energies detected.

Table 1 lists the factors used to convert counts per minute (cpm) for a 2X2 NaI detector to uR/h as a function of gamma ray energy. These data are taken from the U.S. Nuclear Regulatory Commission's "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", NUREG-1507, (NRC 1998). According to these data a gamma ray of energy of 600 keV has a conversion factor of 1010 cpm per µR/h. Therefore, if a count rate of 50,000 were detected, the exposure rate would be about 50 µR/h.

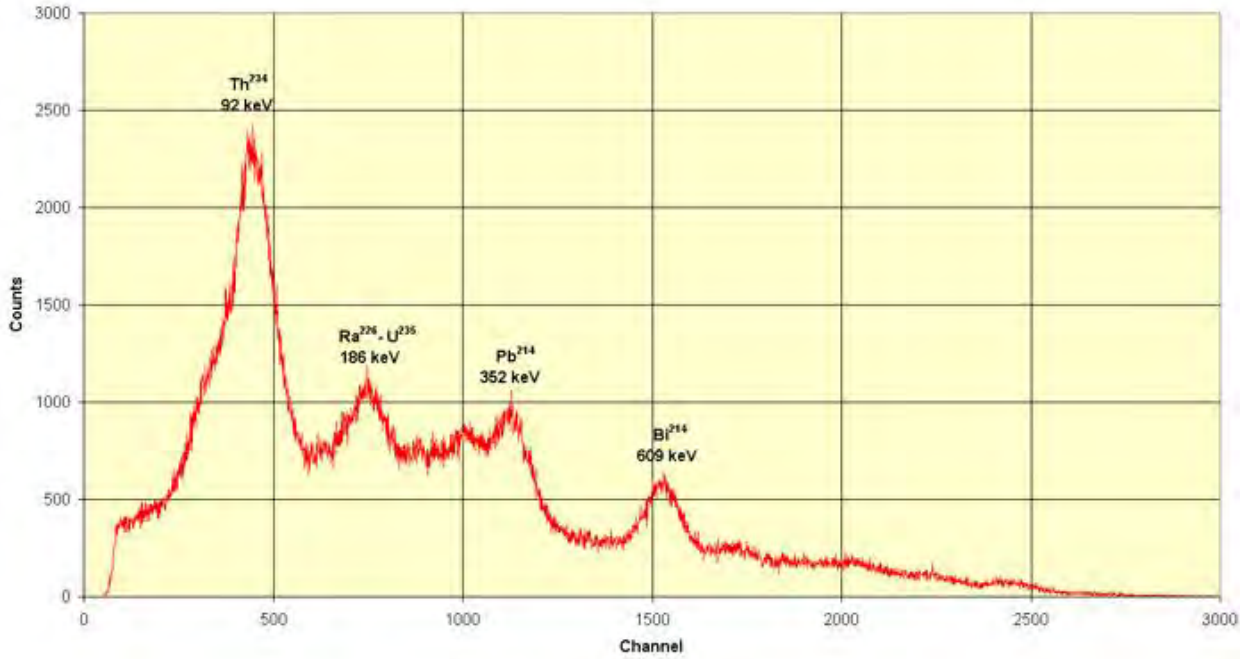


Figure 1. Uranium Outcrop Grab Sample

Table 1. NaI scintillation detector cpm per µR h^{-1} values

Gamma Energy (keV)	2" x 2" NaI Detector (cpm/µR/hr)
20	2200
30	5160
40	8880
50	11800
60	13000
80	12000
100	9840
150	6040
200	4230
300	2520
400	1700
500	1270
600	1010
662	900
800	710
1000	540
1500	350
2000	260
3000	180

Similarly, a gamma ray energy of 300 keV has a conversion factor of 2520 cpm per µR/h, and a 50,000 cpm count rate would be equal to an exposure rate of about 20 µR/h. The conversion

factor for a gamma ray energy of 200 keV is 4230, which converts a 50,000 cpm count rate to an exposure rate of approximately 12 μR/h.

As can be discerned from these data, conversion of gross count rate data to μR/h depends on the gamma energies detected and the data report must be qualified using an appropriate conversion factor. Typically, a qualification statement is added that specifies the gamma ray energy used to convert the data to μR/h. For natural uranium in equilibrium with its progeny, use of an average gamma enery of 300 keV and corresponding conversion factor of 2520 cpm per μR/h would be conservative. Those values are used for this report.

Converting Gross Count Rate Data to pCi/g of Ra-226

The Department of Energy maintains a set of calibration facilities to support the environmental measurement of radioactive radium, uranium, thorium, and potassium. One such facility is located near Grants, NM, on highway 605 north of Milan. This facility contains six pads of concrete, approximately 42 inches in diameter, mixed with varying concentrations of U-238 ore (identified as the Ra-226 pad since the Ra-226 would be in secular equilibrium with the U-238), thorium 232 (Th-232), and potassium-40 (K-40). A "background" pad (GPB) is included that has no incremental radioactivity added to that which would be present naturally in concrete. Table 2 presents the radionuclide concentrations in these pads.

Table 2. Calibration Pad Concentrations

Pad Designation	Concentration (pCi/g)[a]			Dry Bulk Density (g/cm^3)[b]	Partial Density H_2O (g/cm^3)[b]
	Ra-226	Th-232	K-40		
GPK	0.58 ± 0.82	0.01 ± 0.06	51.53 ± 1.46	1.96	0.127
GPL	87.78 ± 14.32	0.50 ± 0.10	15.58 ± 1.02	1.90	0.165
GPH	375.74 ± 45.14	0.61 ± 0.10	15.93 ± 1.62	1.91	0.142
GPT	6.57 ± 3.14	30.23 ± 0.80	14.94 ± 1.02	1.89	0.146
GPB	0.0 ± 0.3	0.0 ± 0.3	0.0 ± 0.1	NA	NA
GE2	83.13 ± 15.42	0.70 ± 0.10	12.93 ± 1.02	1.85	0.237
GE4	396.66 ± 49.70	0.80 ± 0.12	12.20 ± 1.48	1.84	0.148

[a] Uncertainties are 95 percent confidence level.
[b] Uncertainties for these values have not been determined.

Prior to performing the radiation survey of the Navajo AUM sites, Weston collected gross gamma count rate data above each of these calibration pads using the 2X2 NaI detectors. Count rate measurements were collected on contact with the pad and at a height of 18 inches above each pad. Measurements collected on contact were more consistent than those collected at 18 inches because of variability in the actual height at which detectors were held during the 18-inch measurements. These data are presented in Figure 2, which compares count rate of the instrument in cpm versus gamma emission rate from each pad in gammas per minute.

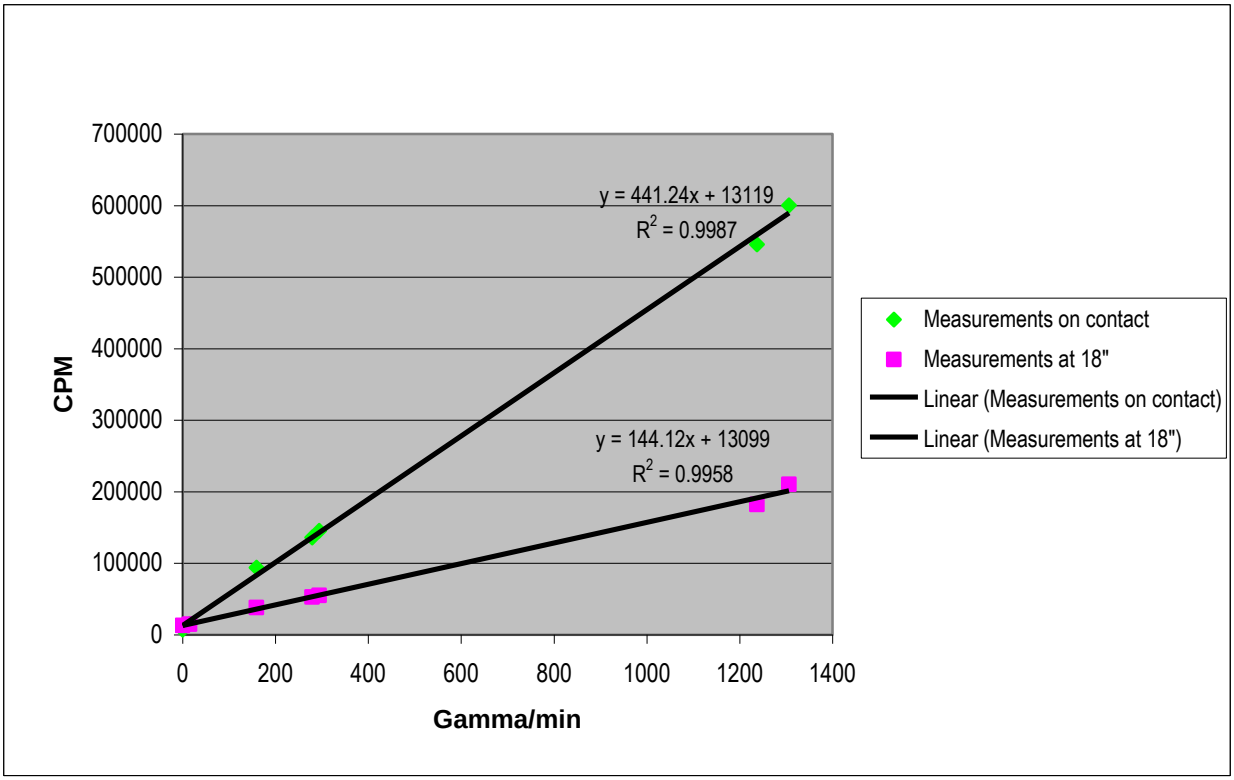


Figure 2. Least square fit of calibration pad data

Pad concentrations are converted to gamma emission rates because each pad contains a mixture of U-238 and progeny, Th-232 and progeny, and K-40. The gamma emission rate from each pad is the sum of all gamma rays with energy greater than 60 keV and abundance greater than 1%.

The gamma emission rates from each pad were calculated using the isotopic concentrations in each pad and the gamma emission rates for the individual isotopes contained in the pads. The isotopic gamma rates used for these calculations were:

K-40	0.246 gamma/min per pCi/g
U-238	3.276 gamma/min per pCi/g
Th-232	4.416 gamma/min per pCi/g

Using the linear relationships in Figure 2, the instrument count rates can be estimated that would be detected from varying concentrations of U-238 assuming fixed concentrations of K-40 and Th-232. For example, assuming a K-40 concentration of 15 pCi/g (15 pCi/g x 0.246 = 3.69 gamma/minute) and a Th-232 concentration of 1 pCi/g (4.416 gamma/minute) and a U-238 concentration of 5 pCi/g (5 pCi/g x 3.276=16.38 gamma/minute), the sum of all three is 24.49 or approximately 25 gamma/minute. Inputting this value into the two linear equations on Figure 4 results in an instrument count rate of approximately 24,000 cpm for measurements made on contact, and 17,000 cpm for measurements made at an elevation of 18 inches.

For a U-238 concentration of 15 pCi/g, the calculations described above result in 49.14 gamma/minute for U-238 and a total of approximately 57 gamma/minute including contribution

from K-40 and Th-232. The instrument response using this same approach is estimated to be 38,000 and 21,000 cpm on contact and at a height of 18 inches, respectively.

It is important to note that these calculations are based on measurements from radiation sources of approximately the same dimensions as the calibration pads, i.e. 42 inches in diameter and infinite thickness. Any of the following factors are likely to vary during field measurements and may significantly impact the instrument response factors described above:

1. The area containing elevated concentrations of uranium and other radionuclides was typically much larger than the calibration pads, and in some cases small hot spots were encounters than the pads. Either situation impacts the instrument response factors.
2. The surfaces measured were not flat, which allowed the distances between the source and the detector to vary. In addition, measurements were sometime made in ravines or near vertical faces of rock or soil so that gamma rays were contributed from the sides of the detector, not just from below the detector.
3. The concentrations of K-40, Th-232, and other isotopes were significantly different than the values used above, as is typical in nature.
4. The distances between the detectors and the ground fluctuated due to variations in monitoring methods from one technician to another and difficulties encountered in rough terrain.

References

U.S. Nuclear Regulatory Commission (NRC 1998). "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", NUREG-1507, Washington, DC. 1998

APPENDIX C:

Photo Documentation

Northeast Church Rock - Quivira
Site Photographs

Photo 1. Road and bridge separating NE Church Rock and NE Church Rock 1

Photo 2. Entrance to NE Church Rock 1 gate and bend in road

Photo 3. Bend in road and culvert outfall

Photo 4. NE Church Rock 1-East drainage to arroyo

Photo 5. Culvert outfall from NE Church Rock 1-East leading to arroyo

Photo 6. Arroyo east of NE Church Rock 1-East mine site

Photo 7. Convergence of arroyos from NE Church Rock 1 and NE Church Rock 1-East

Photo 8. Livestock in arroyo

Photo 9. Bridge crossing arroyo between NE Church Rock and NE Church Rock 1

Photo 10. Arroyo below NE Church Rock 1

Photo 11. Northwest arroyo (West of Quivira Mines)

Photo 12. Southwest arroyo (West of Quivira Mines)

Photo 13. Surface measurement in South arroyo (West of Quivira Mines)

Photo 14. Augering for subsurface measurements

Photo 15. Augering for subsurface measurements

Photo 16. Augering for subsurface measurements

Photo 17. Augering for subsurface measurements

Photo 18. Collecting subsurface measurement in auger hole

Photo 19. Pond near Benally residence

Photo 20. Draining from pond near Benally residence

Photo 21. Benally residence

Photo 22. Corn Field near Benally residence

Photo 23. Arroyo north of corn field

Photo 24. Screening at NE Church Rock 1 mine

Photo 25. Screening at NE Church Rock 1 mine

Photo 26. NE Church Rock 1-East mine

Photo 27. NE Church Rock 1-East mine